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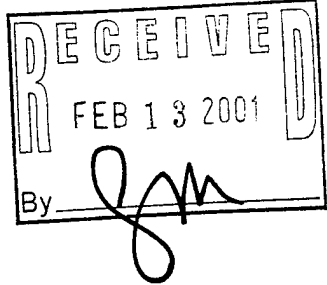
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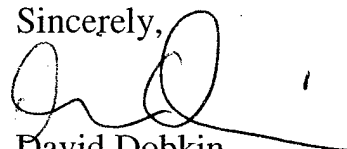# Memorandum of Transmittal

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REPORT TITLE: *AASERT: Software Tools for Experimentation in Computational Geometry*

is forwarded for your information.

Sincerely,

David Dobkin,
Principal Investigator

Final Report on Project: *AASERT: Software Tools for Experimentation in Computational Geometry*

Dobkin has been involved in two projects involving the transfer of computational geometry to problems from other domains. Together with colleagues at AT&T Research, he has built a path planning system that traces smooth paths through constraint fields. This system is a part of a larger system to do automatic layout of graphs. The algorithms developed have been animated as an aid to presenting the underlying ideas.

Dobkin's research has considered problems in computer graphics and visualization. The work has aimed to bring theoretical tools to practical problems as well as to develop tools with which to aid in the building of geometric software. We have studied the problem of creating a parameterization of the surface of a mesh that can be applied at multiple resolutions. Such a parameterization has a number of applications. We were originally motivated by the desire to be able to progressively transmit meshes by having a hierarchical representation. To solve this problem Dobkin has worked with Aaron Lee, to develop the MAPS (Multiresolution Adaptive Parameterization of Surfaces) system for finding a full surface parameterization. The parameterization is computed in hierarchical fashion. While previous methods removed a small number of vertices per iteration, we are able to remove a fraction of the vertices. As the name suggests, the parameterization is also adaptive. Thus, we can use it as a basis of resampling the surface to smooth the mesh, make it more regular or to supersample areas of high curvature.

The MAPS system is built by generalizing the Dobkin-Kirkpatrick hierarchy to non-convex polyhedra. At each level of the hierarchy we identify an independent set of vertices that can be removed to simplify the polyhedron. Since no two removed vertices are adjacent, the holes that are created are isolated from one another.The process at each level is then completed by retriangulating each of the holes without introducing new vertices. In the convex case, there was an obvious technique for retriangulation. In the non-convex case, there is no easy way to retriangulate the hole created by the removal of a saddle point. We solve this problem by using the harmonic map to flatten the neighborhood of the removed point. In creating the hierarchy, we also control those vertices that are removed at any level. The user can specify vertices that are to be not removed (e.g. to preserve

features). Also, in going from level to level in the hierarchy, we only remove some of the vertices of the independent set preserving those vertices of high curvature while removing those of low curvature. We have determined empirically levels at which the hierarchy should be terminated, rather than proceeding to a base tetrahedron as we suggest doing in the convex case. This results in a mapping from an original mesh of tens of thousands of triangles to a base domain of 100 or fewer triangles. By computing barycentric coordinates for each removed vertex in terms of the original vertices, each vertex of the original mesh is represented as a linear combination of the vertices of the base domain. From this, the surface is parameterized.

The system has been recently applied to the problem of creating a smooth mesh between meshes. To create a morph between meshes representing two heads, we would identify key features of the 2 meshes. For example, we might match eyes to eyes (as points), mouths to mouths (as polylines) and ears to ears (as polygons). We then reduce both meshes to their base domains while preserving their identified features. At the base domain level the number of vertices is much smaller and so we can tolerate a quadratic time algorithm. We now extend the identification from the features to all vertices using a relaxation technique. We next compute the metamesh, a mesh that is the overlay of the 2 original meshes. Because the vertices have been identified, the metamesh contains the information needed to construct the morph. By isolating areas of the metamesh, we can vary the morph temporally as well. As a result, we can morph the hairline of one person to the face of another.

Dobkin, together with Alejo Hausner, have continued work on building an algorithm animation system. Their system is built in Java and so algorithms implemented in the system are easily accessible via the world wide web. There is significant support for geometric primitives and most of the basic geometric algorithms can be seen as animations. A paper and video describing the GAWAIN system appeared in *GAWAIN: Visualizing Geometric Algorithms with Web-based Animation*".

Publications

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